A STUDY OF THE ECONOMIC PROPORTIONS OF STEEL TRUSS BRIDGES

BY

MELVIN WHEELER JACKSON

B. Eng., University of Southern California, 1943
M. S., University of Illinois, 1945

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENGINEERING
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1948

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A STUDY OF THE ECONOMIC PROPORTIONS OF STEEL TRUSS BRIDGES

The economic proportions of a bridge depend considerably upon the least weight of metal in the bridge because structural contract prices are usually based on weights. There are other factors which must be considered in choosing the outline of a bridge, such as appearance, stiffness, clearances, fabrication costs, erection costs, proportion of details, etc., but these are frequently intangible and impossible to evaluate accurately, and are not considered in the thesis. The present study is confined to a consideration of least-weight depths.

Many organizations have built thousands of bridges, but information gained which might be useful to the engineering profession in general, in a study of the present problem, seems to be buried completely in private files, unavailable, or else not available in usable form. Not being able to obtain comparable data on a sufficient number of existing structures for a study of significant factors in the economic depth, the writer found it necessary to prepare preliminary designs for approximately 200 trusses, of which 69 are presented in the Appendix to the thesis as comparable and applicable. It is on the basis of these designs that the conclusions presented have been obtained. Because of the magnitude of the work involved, it was necessary to limit the present investigation to parallel-chord railroad bridges of simple spans. All designs were based on double-track, open timber deck, Warren trusses, and the 1947 American Railway Engineering Association Specifications were used as a guide throughout. In the truss designs, an attempt was made to follow good design procedure rather than strive for the absolute least possible weight in each individual case; it is on this basis that all designs are comparable.

The designs presented are complete to the extent of selection of sections for all members. The stresses were computed considering the load on the truss applied entirely at the panel points on the lower chord. In all cases a fixed percentage was added for the weights of details and for the weights of bracing, respectively 37½ per cent and 10 per cent of the weight of the members of the two trusses. The weights of the members were based on the gross areas of the cross-sections and the center-to-center lengths of the members.

Four variables were considered in the designs, namely, panel length, number of panels, depth of truss, and loading. The first two variables, of course, included variation in span lengths. Designs were presented for trusses for four or five depths that varied by intervals of 5 feet for loadings of E-48, E-60, and E-75, for combinations of panel lengths of 24, 30, and 36 feet, and for 6, 8, 10, and 12 panels, but no span exceeded 300 feet. Of the possible combinations of variables, sixteen cases were investigated; the results could be extended to cover other possible cases.

An analysis of the distribution of the truss weight within the truss was made for fourteen of the trusses, by computing the per cent of the total weight of the truss which was contributed by each member. This was broken down further to show the contribution from each of the types of stress on each member. The analysis of these factors seemed to show that small variations in the dead load ,live load, or in the impact formula due to the application of other specifications or to the judgment of different designers would have no significant effect on the weight-depth curves presented.

In studying the weight-depth curves for a given case, it is very difficult, if not impossible, to locate the exact point of minimum weight because variations in depth of one or two feet for actual designs would give an irregular scatter of points, as it is obviously impossible to secure areas of members that will exactly duplicate the calculated require-

ments for relatively small variations in total stress. It would only be by chance that the actual least-weight depth would coincide with the theoretical as indicated by the general trend. For this reason it was necessary to have some means of showing general trends. Designs prepared by different persons for identical conditions will not ordinarily agree in total weight more closely than one or two per cent, due to the many factors involved in applying specifications. Therefore, it seemed a convenient device to establish the range of depth within which the plotted data would differ from the minimum value no more than one per cent. In most cases this placed the least-weight depth within a range of about 10 feet. This range in itself indicates that a determination of the "exact" least-weight depth is not of great practical importance; rather, it is a useful guide to the judgment of the engineer. It is for this reason that any algebraic expression for least-weight should show the influence of various variables which may be involved.

From a study of the least-weight depths in each of the sixteen cases presented, an empirical expression was formulated. It was desired to obtain as simple an expression as possible, and the following was obtained:

$$d = 0.21\ p\ n^{\frac{1}{2}}\ W^{\frac{1}{3}},$$

in which d is the least-weight depth, p is the panel length, n is the number of panels, and W is the load in kips per foot of bridge which under the conditions set will produce the maximum chord stress. This formula satisfactorily fits the data from the designs in all sixteen cases of least-weights studied. In comparison, advice in current books of the type that the economic truss-depths should vary from one-fifth to one-seventh of the span is not very helpful. Existing formulas of the general type,

$$d = 1.15\ L^{\frac{3}{5}},$$

were found to agree with design results only partially. On

the basis of the designs presented, the proposed formula appears to be a better guide for the judgment of the engineer in selecting a least-weight depth for the type of truss studied than existing formulas.

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